Experiment Isotopic Data Compiled by the OECD/NEA EGADSNF

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INTRODUCTION

An essential component of computational modeling and simulation is the availability of well-qualified experimental benchmark data against which calculation systems can be validated and the bias and uncertainty associated with the codes and data can be evaluated.

The validation process is extremely important for safety and licensing to demonstrate that adequate margins for uncertainty have been included in the calculations. For safety evaluations involving spent nuclear fuel, the isotopic compositions and resulting activities calculated using depletion and decay codes must be validated against experimental determinations of the spent fuel content. In this process the isotopic concentrations predicted by the codes should be compared with corresponding measurements of spent fuel made by destructive analysis as a fundamental part of any code performance evaluation.

In recent years there has been growing international interest in acquiring high-quality assay data that can be used to validate code calculations, particularly for modern fuel designs and high burnup fuels and for a wider range of nuclides important to nuclear criticality safety, radiological safety assessments, and decay heat. Assay data are required to validate a broad range of reactor and fuel-cycle applications, including reactor core simulation, postulated severe accident analysis, spent fuel handling, spent fuel transportation and interim storage, reprocessing, nuclear safeguards, and final fuel repository evaluations.

In some cases researchers working on depletion code development have noted a general lack of available assay measurements that can be used to benchmark and validate their code calculations for spent fuel compositions. This perception is due in part to the fact that data have been reported in diverse publications over many years, many experimental reports are difficult to access, and there has not been a concerted and funded effort to compile and consolidate available measurements that can be easily accessed by code developers and analysts for validation.

In response to the increased interest in fuel isotopic measurements and needs for consolidation and documentation of available data, an Expert Group on Assay Data for Spent Nuclear Fuel (EGADSNF) was formed in 2007 as a working group of the Organisation for Economic Cooperation and Development (OECD)/Nuclear Energy Agency (NEA) Working Party on Nuclear Criticality Safety (WPNCS). Although the group was formed by the Expert Group on Burnup Credit to coordinate isotopic assay data activities and facilitate collaboration between countries developing or implementing burnup credit in their nuclear criticality safety methodologies, the group recognized the need and value of assay data for a broad range of spent fuel applications, and the EGADSNF includes members representing not only the WPNCS, but also members from the standing technical Committee on the Safety of Nuclear Installations and the Integration Group for the Safety Case of the Radioactive Waste Management Committee. Member countries currently active in the EGADSNF include Belgium, the Czech Republic, France, Germany, Japan, Slovakia, Spain, Sweden, the United Kingdom, and the United States.

The experimental database of spent fuel measurements maintained by the OECD/NEA is web-accessible. SFCOMPO (database of Spent Fuel Compositions) contains measured isotopic data, mostly for light water reactor (LWR) fuels, for about 250 fuel samples. This paper summarizes the status of SFCOMPO and current activities to expand and improve the database.

ACTIVITIES OF THE OECD/NEA EGADSNF

The EGADSNF is focused on experimental data and issues concerning the isotopic composition data from spent nuclear fuels, especially for LWRs such as pressurized water reactors (PWRs), boiling water reactors (BWRs), and Vodo-Vodyanoi Energetichesky Reactors (VVERs). The main activities currently include

- expanding the database of available isotopic assay data by increasing the number of fuels samples, increasing the enrichment and burnup range, and expanding the reactor types beyond mainly LWR fuel;
- improving the formats and structure of the spent fuel database to include more detailed information and measurement uncertainties;
- providing recommended fuel design and operating history information needed for computational analysis and validation;
- evaluating potential uncertainties due to missing or incomplete experiment documentation;
- documenting radiochemical analysis techniques, typical accuracies, data reduction methods, and best practices based on previously laboratory experience; and

- publishing a final state-of-the art report on assay data of spent nuclear fuel.

SFCOMPO EXPERIMENTAL ISOTOPIC DATABASE

The SFCOMPO database is a compilation of public experiments that contains fuel assembly design information, reactor operating histories, and measured isotopic contents for 246 spent fuel samples from reactors operating with UO_2 fuel. The website for SFCOMPO is http://www.nea.fr/sfcompo/.

The first version of SFCOMPO was established in the late 1990s by the Japan Atomic Energy Agency (JAEA) to summarize and make isotopic validation data accessible for use by the criticality safety community. In 2002 it was transferred to the OECD/NEA to maintain and coordinate distribution of data to the nuclear engineering community. The experimental data currently archived in SFCOMPO is summarized in Table I.

NEW EXPERIMENTAL DATA

One of the main outcomes of the EGADSNF is to update and expand the SFCOMPO database. This is accomplished through the collaboration of the NEA member countries. This collaboration is particularly beneficial considering the high cost of initiating new experimental assay programs (fuel transportation, hot cell facilities, radiochemical analysis, and waste management), limited resources, and experience of many countries in conducting high-precision isotopic measurement programs.

During the past year the members of the expert group have compiled measurement data from a number of additional experimental programs and have contributed the data to the NEA. Some data were collected from previously unpublished measurements, while some were data that had not been widely available. Other data have been added from relatively recent experimental programs and include new UO_2 and mixed oxide (MOX) measurements. Planned additions include those below.

- New measurements for VVER 440 Novovorenezh reactor fuel will be performed under the U.S. Department of Energy/ International Science and Technology Center program.
- UO_2 and MOX fuel measurements performed under the ARIANE International program will be made publicly available by Oak Ridge National Laboratory.
- Sweden has contributed a set of experimental data from the BWR Swedish Formark-3 reactor fuel measured at Harwell (Sweden) and Dimitrovgrad (Russia).
- Experimental data from advanced gas-cooled reactor (AGR) and Magnox fuels have been provided by the United Kingdom National Nuclear Laboratory. The data from both reactor types are already available at the EGADSNF webpage and will soon be uploaded to SFCOMPO.
- Spain will provide data for seven samples from the Vandellos PWR reactor with a burnup of up to 75GWd/t.
- The Japanese Nuclear Energy Safety Organisation has analyzed data from a new measurement program for fuel from BWR (9×9) with a burnup of 55GWd/t and a new measurement program that includes high burnup BWR fuel (35–70 GWd/t). The assay data include fission products.
- Measurements of Three Mile Island-1 reactor fuel made at GE-Vallecitos and Argonne National Laboratory (ANL) that include extensive fission product data (including all fission product isotopes considered in burnup credit) will be added to the database in the future.
- Germany has contributed isotopic measurements on full-length Obrigheim spent fuel assemblies made at the Karlsruhe Reprocessing Plant (WAK), measurements not currently included in SFCOMPO.

The new measurements proposed for addition to SFCOMPO are summarized in Table II.

SUMMARY

SFCOMPO is a centralized open source of spent fuel assay data and is available through the website of the OECD/NEA. Current activities of the EGADSNF are designed to greatly expand the amount of data currently archived in the database and improve the documentation. Future activities being considered by the group include evaluations of the experimental data by experts in reactor fuels, radiochemistry, and computational analysis. The EGADSNF's activities and the reports compiled to date are available on the OECD/NEA website at http://www.nea.fr/html/science/wpncs/ADSNF/index.html.

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Table I. Spent Fuel Assay Data Currently in SFCOMPO

Reactor	Country	Type	Assembly Design	Fuel Type	Sample Number
Obrigheim	Germany	PWR	14×14	UO_2	23
Gundremmingen	Germany	BWR	6×6	UO_2	12
Trino Vercellese	Italy	PWR	15×15	UO_2	39
JPDR	Japan	BWR	6 ×6	UO_2	30
Tsuruga-1	Japan	BWR	7×7	UO_2	10
Fukushima-Daiich-3	Japan	BWR	8×8	UO_2,UO_2-Gd_2O_3	36
Fukushima-Daini-2	Japan	BWR	8×8	UO_2,UO_2-Gd_2O_3	18
Mihama-3	Japan	PWR	15×15	UO_2	9
Genakai-1	Japan	PWR	14×14	UO_2	2
Takahama-3	Japan	PWR	17×17	UO_2,UO_2-Gd_2O_3	16
Cooper	USA	BWR	7× 7	UO_2	6
Monticello	USA	BWR	8×8	UO_2,UO_2-Gd_2O_3	30
Calvert Cliffs No.1	USA	PWR	14×14	UO_2	9
H.B. Robinson Unit 2	USA	PWR	15×15	UO_2	6

Table II. New Experimental Data to Be Included in SFCOMPO

Country	Reactor	Type	Measurement Facility	Assembly Design	Number of Samples	^{235}U Enrichment [wt%]	Burnup [GWd/t]
Germany	Obrigheim	PWR	ITU/IAEA/WAC/IRCh	14×14	5	3.13	27–29
	Obrigheim	PWR	ITU	14×14	1	3.2 Pu***	37
Japan	Fukushima-Daini-2	BWR	NFD	8×8-4	46	3.0	9–62
	Fukushima-Daini-1	BWR	JAEA	9×9-9	11	3.4	36–69
			NFD	9×9-7	6	3.4	61–78
	Tsuruga-1	BWR	NFD	8×8-2	2	3.1/4.6 Pu**	31–39
	Not yet opened	PWR	JAERI	17×17	5	3.2	22–39
Netherlands	Dodewaard	BWR	SCK•CEN/PSI	6×6	5	4.9/6.4 Pu**	34–56
Russia	Novovoronezh (ISTC-2670)	VVER-440	RIAR (Russia)	Hexagonal	8	3.6	39
Spain	Vandellós	PWR	Studsvik Nuclear	17×17	7	4.5	43–74
Sweden	Forsmark 3	BWR	Studsvik Nuclear, Dimitrovgrad, Harwell	SVEA-100	1	4	60
Switzerland	Beznau-1	PWR	SCK•CEN/PSI	14×14	3	4.3–6.01 Pu*	40–59
	Gösgen		ITU/SCK•CEN	15×15	3	3.4/4.1	29–60
	Beznau-1		ITU, Karlsruhe	14×14	6	3.7–5.5 Pu**	22–63
UK	Hinkley 3/4	AGR	AERE Harwell and AEE Winfrith	Annular	27	1.54–2.55	1–26
	Hunterston 3	AGR	AERE Harwell and AEE Winfrith	Annular	2	2.0	13–16
	Hunterston A	Magnox	AERE Harwell	Fuel rod	5	0.711	3–9
	Bradwell	Magnox	AERE Harwell	Fuel rod	1	0.711	9
USA	TMI-1	PWR	GE-Vallecitos	15×15	8	4.7	23–30
			ANL		11	4.0	45–56

* (Pu+Am)/(U+Pu+Am) ** Pu/(U+Pu) *** Pu fissile